Tracing the co-evolution path of super massive black holes and spheroids with Ultra-Luminous Infrared Galaxies

（別紙様式５）

論 文 内 容 要 旨

(NO. 1)

氏　　名	CHEN Xiaoyang	提出年	平成　31　年
学位論文の 題　　目	Tracing the co-evolution path of super massive black holes and spheroids with Ultra-Luminous Infrared Galaxies (大光度赤外線銀河で探る超大質量ブラックホールと銀河スフェロイドの共進化経路)		

論 文 目 次

（別紙様式５）

論　文　要　旨

Ultra-luminous infrared galaxies (ULIRGs, with infrared luminosity greater than 10^12 L⊙) are a population of the most intensely star-forming galaxies in the local universe, with star formation rates (SFR) of 100-1000 M⊙/yr. They are thought to represent rapidly growing phase of massive galaxies before quenching of their star formation by the feedback effect of stellar wind and/or AGN outflow, and both of star formation and AGN show their peak activities during ULIRG phase. Although their contribution to the cosmic star formation rate density (SFRD) is low in the local universe due to their low number density, ULIRGs start to dominate the cosmic SFRD in the high redshift universe at z > 1. Therefore ULIRGs are an important population to understand the growth of supermassive blackholes (SMBH) and their host galaxies.
In order to understand the stellar population and outflow properties of ULIRGs to examine the merger-induced evolutionary scenario, we construct a 90 μm flux limited catalog of 1028 ULIRGs, which are selected from the AKARI FIR all-sky survey by utilizing the SDSS optical and WISE MIR imaging data. 203 out of the 1028 ULIRGs are spectroscopically identified by SDSS and Subaru/FOCAS observations, in which 149 ULIRGs possess galaxy dominated optical spectra. The sample is unique since it is a statistical sample of far-infrared (FIR) selected galaxies with reliable identification from middle-infrared (MIR) pointing, and includes the ULIRGs with broad emission lines which suggest fast outflows. A self-consistent spectrum-SED decomposition method, which constrain the stellar population properties in the SED modeling based on the fitting result of the spectrum, has been developed for a detailed analysis for the 142 ULIRGs with galaxy dominated spectra. They are identified as the most massive galaxies (Mstar ~ 10^11 M⊙-10^12 M⊙), associated with intense star formation activity (SFR~ 400M⊙/yr). 12 ULIRGs possess SFR exceeding 1000 M⊙/yr and the ULIRG, J115458.02+111428.8, even shows SFR up to 5000 M⊙/yr, indicating one of the most intense starbursts at z ~ 0.5. The ULIRGs cover a large range of AGN activity, with bolometric luminosity from 10^10 L⊙ to 10^13 L⊙, and the outflow velocity measured from [OIII] 5007Å emission line shows a significant correlation with the AGN bolometric luminosity. Several galaxies show extremely fast outflow with vout close to 2000 km/s. The outflow velocity of five ULIRGs even exceeds the escaping velocity of the host halos. However, the co-existence of the strong outflow and vigorous starburst suggests that the star formation has not yet been quenched by the outflow during the ULIRG phase. By deriving distributions of stellar mass, SFR, mass fraction of young stellar population, and dust extinction, we find no significant discrepancies between the properties of stellar population in ULIRGs with weak and powerful AGN. The results are not consistent with the merger-induced evolutionary scenario, which suggests that the early-stage SF dominated ULIRGs show younger stellar populations

and smaller stellar mass compared to the late-stage AGN dominated ULIRGs.
In order to examine the nature of candidates of ULIRGs below the SDSS spectroscopy survey limit, we have been conducting the spectroscopic follow-up observations with FOCAS on the Subaru telescope. Among seven optically-faint ULIRGs, we found a ULIRG, AKARI-FIS-V2 J0916248+073034, which indicates signatures of an extremely strong outflow in its emission line profiles. Its [OIII] 5007Å emission line shows FWHM of 1830 km/s and velocity shift of −770 km/s in relative to the stellar absorption lines. Furthermore, low-ionization [OII] 3726Å 3729Å doublet also shows large FWHM of 910 km/s and velocity shift of −380 km/s. The long-slit spectroscopy 2D image shows that the outflow extends to radius of 4 kpc. The mass outflow and energy ejection rates are estimated to be 500 M⊙/yr and 4×1044 erg/s, respectively, which imply that the outflow is comparable to the most powerful ones observed in ULIRGs and QSOs at $0.3 < z < 1.6$. However, the central AGN activity estimated from the SED decomposition is relatively weak. One possible scenario is that currently the AGN is in a fading status, while the outflow reflects a long term effect of the central engine. The results suggests the possibility of another evolution sequence, in which the AGN decays before the termination of the star formation in the host galaxy, and indicates that the cumulative effect of AGNs feedback on the star formation in the host galaxy could be limited.

別　紙

論文審査の結果の要旨

Chen Xiaoyang 氏の博士論文は、銀河バルジ部分の形成とその中心に見られる超大質量ブラックホールの共進化の過程を解明することを目的としている。共進化の重要な部分は激しい星形成活動と活動銀河中心活動を示す大光度赤外線銀河の中で起こっていると考えられ、銀河合体によりまず激しい星形成活動が引き起こされ、それに引き続いて活動銀河中心核の活動が強くなることにより、銀河内の星間ガスを吹き飛ばす噴出流現象が起こり、最終的に銀河内の激しい星形成活動と活動銀河中心核の活動が停止して、バルジの星形成と超大質量ブラックホールの成長が停止する、というシナリオが提唱されている。Chen 氏の博士論文は、このシナリオで想定される、激しい星形成の後に起こる活動銀河中心核の活動性という時系列の確認と銀河噴出流が実際に銀河全体の星形成に与える影響の定量的な評価により、このシナリオの検証を行うことを目的としている。特に、中間赤方偏移の宇宙にある大光度赤外線銀河の統計的なサンプルを構築するために「あかり」遠赤外線衛星により行われた全天サーベイのデータにスローンディジタルスカイサーベイおよび WISE 中間赤外線衛星の全天サーベイのデータを組み合わせた点が新しく、これにより、これまで IRAS 遠赤外線衛星で構築されてきたよりもより完全な遠赤外線選択のサンプルが構築された。

遠赤外線選択の中間赤方偏移の大光度赤外線銀河に対して星形成率、星質量、超巨大ブラックホールの質量降着率、銀河噴出流の強度を定量的に評価するために、可視光のスペクトルと可視波長域から遠赤外線波長域に渡る測光データを統一的にモデルフィットする独自の手法を開発した。統計的な解析の結果、激しい星形成活動から活動銀河中心核活動へと遷移する時系列の進化は確認されず、また大光度赤外線銀河にみられる銀河噴出流も銀河全体の星形成活動に影響するほど激しくないことが示唆された。これはこれまでのシナリオを否定する大きな研究成果であると認める。個別の天体の噴出流についての結果は査読論文としてすでに出版しており、統計的なサンプルに基づいた議論も査読論文として取りまとめが進められている。これらのことは自立して研究活動を行うに必要な高度の研究能力と学識を有することを示している。したがって，Chen Xiaoyang 氏提出の博士論文は，博士（理学）の学位論文として合格と認める。